
## Faculty of Mechanical Engineering

# ANTILOCK BRAKING SYSTEM CONTROL USING FRACTIONAL GAIN PID CONTROLLER

**AZHAR BIN IBRAHIM**

**Master of Mechanical Engineering (Automotive)**

**2016**

# ANTILOCK BRAKING SYSTEM CONTROL USING FRACTIONAL GAIN PID CONTROLLER

**AZHAR BIN IBRAHIM**

**A report submitted**
**in fulfillment of the requirements for the degree of**
**Master of Mechanical Engineering (Automotive)**

**Faculty of Mechanical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2016**

## DECLARATION

I declare that this report entitled "Antilock Braking System Control Using Fractional Gain PID Controller" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature for any degree.

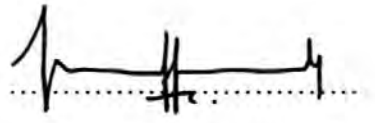
Signature : .....

Name : AZHAR BIN IBRAHIM

Date : JUNE 2016

**APPROVAL**

I hereby declare that I have read this project report and in my opinion this project report is sufficient in terms of scope and quality for the award of Master in Mechanical Engineering (Automotive) Engineering.

Signature : 

Supervisor Name : ASSOCIATE PROFESSOR DR. NOREFFENDY TAMALDIN

Date: 22 JUNE 2016

## DEDICATION

To my beloved family Khadijah Shahrin, Muhammad Amjad, Nur Dayyinah ,

my mother Mariam Yusup and my father Ibrahim Ismail

## ABSTRACT

ABS system is a common technology which is broadly used in automotive field nowadays. Many researchers put their effort on developing the right controller in order to merge with existing ABS system. This determination led to development of several systems for example the implementations of PID controller. Under this project, the main objective is constructing or developing an accurate a quarter vehicle traction model with good ABS controller. Significant vehicle behaviour were examined specifically body and wheel speed, tire longitudinal slip and distance travel experience by the vehicle to investigate the behaviour of ABS under influence of PID and the latest development of FGPID controller. Outcome of the validation experiment shows that response between vehicle model and experimental vehicle are match with an acceptable error. As overall, by the ability of the controller in tracking the changes in slip and changes in the velocity of the vehicle, it is verified that the proposed FGPID controller is very suitable to be used as the controller for the ABS system. The previous FOPID then modified to be $P^{1-\alpha} I^{1-\beta} D^{1-\gamma}$ with the intention to make the controller more efficient, effective and more robust to the changes in parameters and references.

## *ABSTRAK*

*Sistem ABS merupakan teknologi yang digunakan secara meluas dalam bidang automotif hari ini. Kebanyakan penyelidik meletakkan usaha mereka untuk membangunkan sistem kawalan bagi digunakan bersama dengan sistem ABS yang sedia ada.Pembangunan teknologi mendorong kepada penggunaan sistem kawalan seperti PID.Di dalam projek ini pembinaan suku model kenderaan yang tepat dengan sistem ABS menjadi objektif utama. Keutamaan diberikan kepada parameter seperti kelajuan badan dan tayar kenderaan, gelincir membujur tayar dan jarak pergerakan bagi mengetahui dan menyiasat keadaan system ABS dibawah penggunaan PID dan yang terkini FGPID. Secara keseluruhan berdasarkan kepada kebolehan kawalan mengesan sebarang perubahan pada kelinciran,FGPID dikenalpasti berupaya dan sesuai digunakan didalam kawalan ABS. pengubahsuaian dari FOPID yang terdahulu kepada $P^{1-\alpha} I^{1-\beta} D^{1-\gamma}$ adalah bertujuan untuk menjadikan kawalan lebih berkesan,cekap dan lebih kukuh terhadap sebarang perubahan parameter dan rujukan.*

## ACKNOWLEDGEMENTS

I am very indebted to my supervisors Assoc. Prof. Engr. Dr. Noreffendy Bin Tamaldin and Mr Fauzi Ahmad from Faculty of Mechanical Engineering. Without them, I simply would not be here to pursue my master. I would like to thank them for their guidance and suggestions in conducting my studies, especially for their constructive criticisms, encouragement of independent thinking, and allowing me the freedom to pursue my own interests. I would also like to thank to Shahril Izwan and Mohd Rasyidi for providing invaluable input on many aspects of my research and contributing their time and effort throughout this study.

My appreciations are also addressed to MARA and Kolej Kemahiran Tinggi Mara Masjid Tanah for an opportunity to conduct a research study and providing me scholarship. Special thanks go to the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for providing me equipments and work station. Last but not least I would like to thank to all my colleagues Ammar Al Faiz, Rozaini Nafiah , Faizal Jumaat, Saiful Sukardi , As Siddique , Mohd Asyraf Rawi and Ahmad Shahizam from DAF,KKTMMT for their contribution, suggestions and constructive feedback.

## TABLE OF CONTENTS

## LIST OF TABLE

## LIST OF FIGURE

## LIST OF ABBREVIATIONS AND SYMBOLS

| TITLE | SYMBOL |
|---|---|
| Quarter vehicle mass | $m$ |
| Vehicle velocity | $v$ |
| Tire longitudinal force | $Fx$ |
| Aerodynamic force | $Fa$ |
| Air density | $\rho$ |
| Drag coefficient | $C_d$ |
| Effective frontal area | $A_f$ |
| Normal force | $F_z$ |
| Wheel rolling radius | $R$ |
| Road adhesive coefficient | $\mu$ |
| Wheel angular velocity | $\omega$ |
| Traction torque | $\tau_a$ |
| Braking torque | $\tau_b$ |
| Tire longitudinal slip | $S$ |

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

The ABS system is a common technology which is broadly used in automotive field nowadays .The implementation back then was only in aeronautic field now also can be found in the two wheel vehicles like motorcycle. This is because of the awareness for drivers and passenger safety during braking and to avoid accident from happens. As ABS system important to prevent wheel lock during sudden heavy braking, it is compulsory to make sure that the system to runs responsively and accurately.

The situation of braking becomes critical under difference surface which the researcher has categorized into icy, snow, wet and normal road condition. These conditions commonly become a source of a steering stability lose due to long stopping distance (Lennon *et al.*, 1997).

From here the ABS should responsively control the wheel slip so that a maximum friction is obtained and the steering stability is maintained so that the vehicle will stop in shorter distance while maintaining the directional control. ABS is pressurized by hydraulic valve control during antilock operation. The brake efficiency and steering controllability are depending on the amount of time required to open, close or hold the hydraulic valve. By understanding this, precise controller can be provided and developed in order to improve the ABS system.

According to Ming (1997), the ABS controller must deal with the brake dynamics and the wheel dynamics as a whole plant. The main difficulty in the design of ABS control

arises from the strong nonlinearity and uncertainty of the problem. It is difficult and in many cases impossible to solve this problem by using classical linear, frequency domain methods (Drakunov *et el.*, 1997).

## 1.2 Motivation of Study

The configuration of ABS system is run by combining the parameters of different systems like hydraulics, sensors and control electronics. With minor changes in the controller software, the outputs of different system components are also interchangeable since the systems are reliant on each other. Then with advance development in control field, a large amount of types of controllers were introduced. The most basic and widely used in other area instead of ABS control system is PID.

Although from the implementation point of view, PID controller seems easier but tuning it into an appropriate combination is a very tedious job and this is the exact reason which gives scope of developing several tuning algorithms. Particularly for complex mechanical system with certain lag or hysteresis, the PID controller does not yield good result due to nonlinearity. A good control system should ideally have smaller rise time, less overshoot, smaller settling time and steady state error.

After several investigations on related soft computing method, the PID controller is reliable due to the effectiveness on real application. An improvement has been made recently by the addition of FOPID controller .Any change of the parameters and input shows small response in the system.

This brought the idea of enhancing the controller by emphasizing on P characteristic. Gain is added to the P and it is observed that the elasticity of FOPID can be increased. Classical PID controller also improved since there is flexibility in changes of

input and parameters. Named as FGPID fractional gain PID ($P^{1-\alpha} I^{1-\beta} D^{1-\gamma}$) in this project, the controller that concerning a fractional proportional, fractional integrator and fractional differentiator are introduced.

## 1.3 Objective of the Study

1. To model and validate the quarter vehicle traction model to be used as representative of ABS system.
2. To investigate the performance of ABS by using fractional gain PID compared to PID controller.

## 1.4 Scope of the study.

1. Literature review on related fields.
2. Model developments and validation of quarter vehicle traction model using real vehicle.
3. Control design by simulation by using PID controller.
4. Control design by simulation by using FGPID controller.
5. Performance evaluation of PID controller and Fractional Gain PID. Only three parameters are observed in this project which is longitudinal speed, stopping distance and body speed comparison.

## 1.5 Report organization

The research methodology implemented in this study is described as the following steps of works:

### 1.5.1 Modelling and validation of quarter vehicle traction model.

This study begins with the modelling and development of an accurate vehicle dynamic model to describe analytically the dynamic behaviour of a vehicle in longitudinal direction. In this stage, a 2 degree-of-freedom (DOF) quarter vehicle dynamic model is developed. The model that includes hydraulic brake subsystem is then validated experimentally using an instrumented experimental vehicle. Several dynamic braking tests were conducted, which are sudden braking test. The tests are implemented at low speed and medium speed. The behaviours of the vehicle models were then verified with the behaviour of the experimental vehicle.to ensure the effectiveness of the data measured; the same input brake and vehicle speed are used.

### 1.5.2 Control design by simulation of anti-lock braking system using PID controller.

This study then proceeds with the control design by the simulation of antilock braking system (ABS). PID controller were added and evaluated on a quarter car model in the same speed of vehicle such as used in normal braking and validation stages. Performance evaluations of the PID were characterized by the ability of the control strategies to stop a vehicle in shortest period of time and the shortest stopping distance as well as their consistency in providing the optimum target slip.

### 1.5.3 Performance evaluation of FGPID in ABS system in simulation.

The final stage in this study is the experimental investigation of the effectiveness of the FGPID compared to previous controller which is PID. All the simulation studies in normal braking and ABS were then evaluated experimentally and compared with the simulation results. The robustness of the control strategy to tire slip variation was also studied. This is due to the fact that in practical; tire slip of the vehicle may vary depending on the road conditions. The optimum controller then was also implemented on the full vehicle model to examine the efficiency of the controller in full vehicle braking system. It should be noted that all numerical computations and computer simulations were conducted using the MATLAB SIMULINK programming software version R2009B developed by the Math Works, Inc.

## 1.5 Structure and Layout of Thesis

This project report is organized in five chapters. A brief and comprehensive overview of the main points of the research process is shown in Figure 1.1. The thesis contains an introductory chapter which gives a brief introduction on controller involving in ABS control system. This chapter presents previous research findings leading to the objectives of this study. Under this chapter comprises of explanation about how and why the objective is obtained .Following of the project report is includes under this brief description.

Chapter 2: This chapter presents the literature reviews on related subjects concerning this report. In this chapter, the introduction of ABS system controller, Antilock Braking System Control Strategies including the different types of controller and Optimization Tool Selection are reviewed. Review on recently published articles related to ABS control, which relies on PID, is also presented. Finally, the potential of using PID controller for ABS control based, FGPID system is discussed.

Chapter 3: The methodology of this study regarding the modelling and validation of 2 DOF quarter vehicle traction model is presented in this chapter. Some vehicle modelling approaches and modelling assumptions are introduced. Development of instrumented experimental vehicle used to ensure the model validity is also reviewed. PID and FGPID implementation are discussed in detail. The potential benefit of the proposed controller structure will then be finally discussed and presented.

Chapter 4: This chapter presents the controller design for ABS namely PID and FGPID. The results of validation in sudden braking test are discussed and reviewed. There are also discussions about performance evaluation of PID and FGPID under difference road conditions. The findings will be concerning on longitudinal speed, stopping distance and body speed comparison only.

Chapter 5: This chapter summarizes the works done in this entire study, infers conclusions that can be drawn, highlights of the study contributions and is concluded with recommendations for future research work.

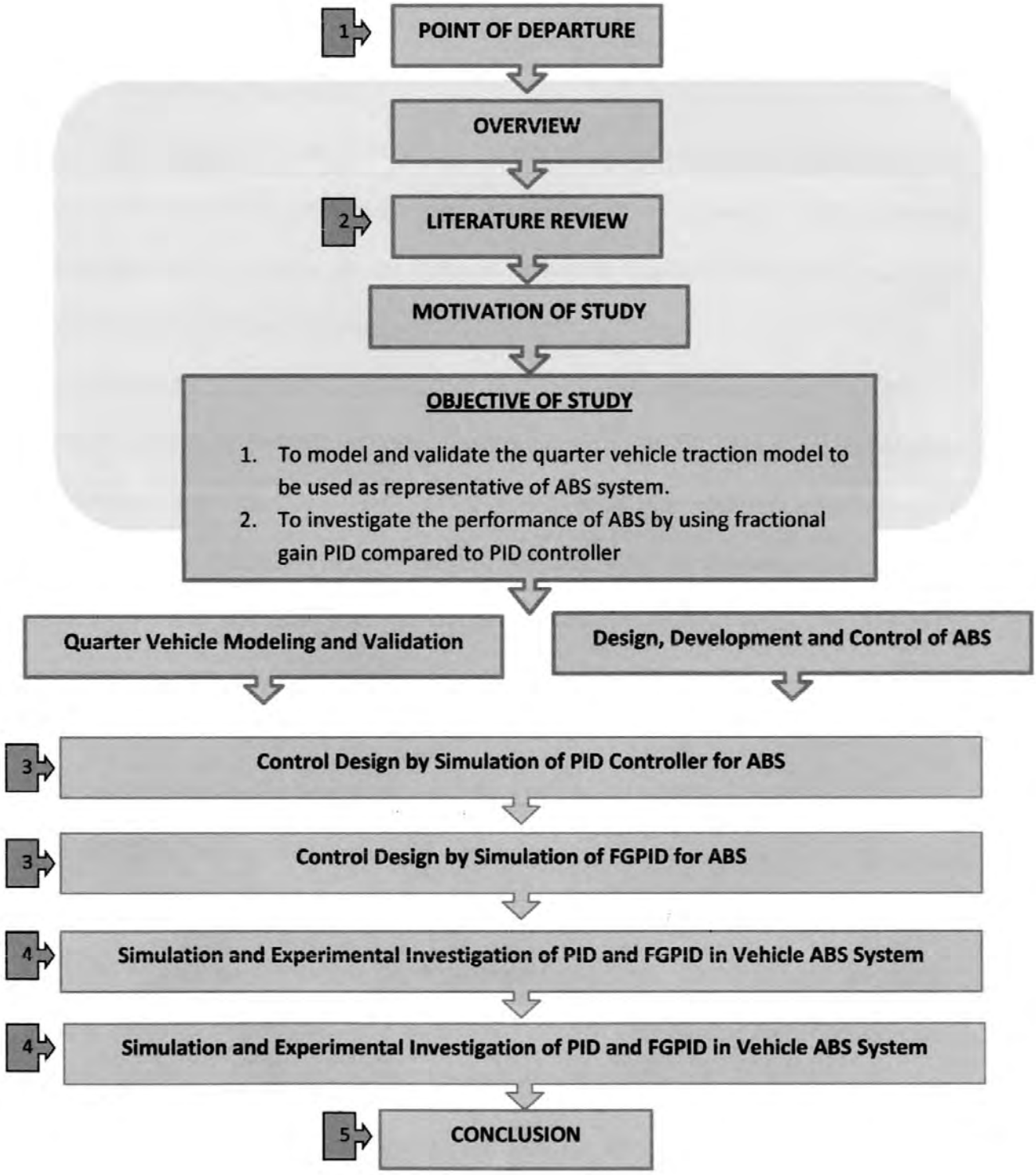



Figure 1.1: Summary of the research process in chapter 1.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Overview of literature.

This chapter will describe details on the review of related development process incur in this study. First part of the review will explain about the need for ABS system and second part will be details on the types of controller involve while in third part will emphasis on the method of tuning.

From the time since the occurrence of the first driving accident dated in 1770, the reduction of driving accident and vehicle safety improvement has been the main objective for researchers and engineers (Hart, 2003). It is strongly proven that an efficient way to stop the vehicle during speed or to prevent accident is by the implementation of brake system. However braking system still can be improved by assisting system. In year 1930, aerospace industry researcher has developed the mechanical ABS system as a solution for this matter. (Maier, 1996).

This development brings the rear only ABS system to be used in high end vehicles in 1960 (Fling *et al*, 1981) and after a few decade, influenced by fast evolution of microcomputers and electronics technologies the movement keep on rising in 1980 (Yoneda *et al.*,1983).Nowadays the technologies has been used in almost all modern vehicle including motorcycle. ABS is designed to ensure the vehicle steerable and stable during heavy braking by preventing wheel lock. This condition is usually initiated while braking on slippery road surface or severe braking. Consequential of this factor, the

distance of the vehicle to stop immediately will be far hence lead to uncontrolled steering stability (Lojko, 2002).

ABS mechanisms work by manipulating the wheel slip so that a maximum friction is gained while the steering stability is maintained. The effective desired, measured by vehicle shortest stopping distance possible and still in directional control.The core on developing the suitable control design is to regulate the wheel velocity. Currently the traction control system (TCS) and vehicle dynamic stability control (VDSC) are also implementing the ABS technologies (P. Hart,2003).

Basic ABS components include: vehicle's physical brakes, wheel speed sensors (up to 4), an electronic control unit (ECU), brake master cylinder, a hydraulic modulator unit with pump and valves.Advanced ABS systems also contain accelerometer to determine the deceleration of the vehicle. Figure 1 below visually explains about the typical ABS involved.

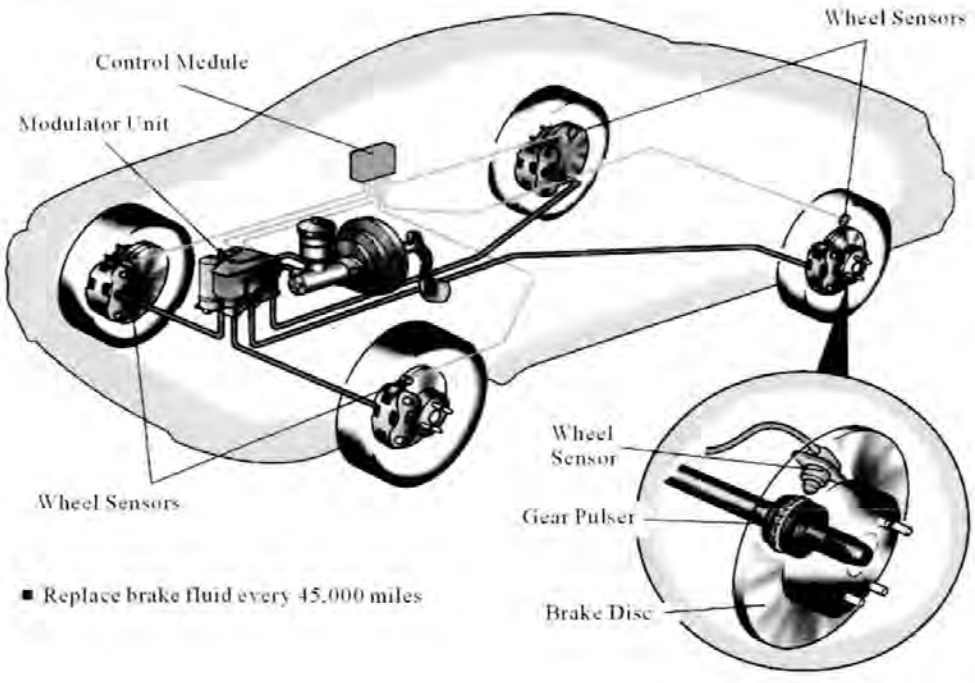



Figure 2.1: ABS component in vehicle (Ulsoy, 1997)

## 2.2 Modelling And Validation Review

The development modern vehicle required more sophisticated system to evaluate. Many researcher struggles to investigate the behaviour on certain system by experimenting it. Computer simulation always had been a choice in order to avoid the cost and risk in actual experiment to build a model of the system.

However the model must be created as close as to the actual system and this only can be done by validating it. Hudha, (2005) said fully validation on a real vehicle is necessary during experiment, other than that will reflected on unpractical model. In this project the quarter vehicle is modelled and validated by actual experiment. The validation with experiment is acceptable when the tendency of the simulation and the experimental data results show similar or significantly match (Ahmad,2014). But validation by actual experiment is not the only way for validation.

Most of the researchers used comparison by using different types of related simulation software such as Carsim and others. According to Shaoyi(2011) the establishment of model and controller based on SIMPACK and MATLAB software is necessary to co-simulate and to get higher accuracy in order to play their respective advantages.

## 2.3 Antilock Braking System Control Strategies

Various control strategies of ABS have been presented in both academic and industrial fields. From many scientific publications in the area of ABS, most of them discussed ABS control strategies and some of them will be reviewed in this section. To simplify the explanation, the topics that will be reviewed in this section are selected for widely known control approaches in the area of ABS.